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Abstract: Background Alternative cannabis regulation models are discussed and implemented worldwide. A baseline scenario under the assumption of no policy or market changes may prove useful to forecast cannabis use and treatment demand and evaluate changes in legislation. Methods Based on data of the Continuous Rolling Survey of Addictive Behaviours and Related Risks on cannabis use, age, gender and nationality from 2011 to 2015, we used general estimating equation analysis to model lifetime and 30-days prevalence from 2015 to 2045 in Switzerland accounting for demographic trends. Results Lifetime prevalence of cannabis use is projected to grow from 28.3% (CI 95% 27.8–28.8) in 2015 to 42.0% (CI 95% 41.0–43.0) in 2045. 30-days prevalence would increase slightly from 2.70% (CI 95% 2.53–2.88) to 3.39% (CI 95% 3.11–3.66). Due to population growth, absolute numbers with past 30-day cannabis use are estimated to increase from 202,784 (CI 95% 189,534–216,035) to 314,302 (CI 95% 288,504–340,100). Among those aged under 30 years no substantial change in lifetime and 30-days prevalence of cannabis use is projected. Larger changes are estimated to occur in the age group 30+. The mean age of past 30-day cannabis users would increase for men with Swiss nationality from 30.3 to 38.7 years. Discussion Population-based survey data and demographic projections can be used to develop baseline scenarios of future cannabis use. Assuming no changes in cannabis legislation, growing absolute numbers of users will likely increase treatment demand. Cannabis use is estimated to increase among the group aged >30 years, which is currently underrepresented in clinical treatment and research. Our findings highlight the need for prospective baseline scenarios to evaluate the impact of legislative changes on cannabis use. Moreover, in Switzerland effective prevention and treatment interventions for cannabis use disorders are required even if cannabis legislation remains unchanged.

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Cannabis use in Switzerland 2015-2045: a population survey based model

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Abstract

Background: Alternative cannabis regulation models are discussed and implemented worldwide. A baseline scenario under the assumption of no policy or market changes may prove useful to forecast cannabis use and treatment demand and evaluate changes in legislation.

Methods: Based on data of the Continuous Rolling Survey of Addictive Behaviours and Related Risks on cannabis use, age, gender and nationality from 2011-2015, we used general estimating equation analysis to model lifetime and 30-days prevalence from 2015 to 2045 in Switzerland accounting for demographic trends.

Results: Lifetime prevalence of cannabis use is projected to grow from 28.3% (CI 95% 27.8-28.8) in 2015 to 42.0% (CI 95% 41.0-43.0) in 2045. 30-days prevalence would increase slightly from 2.70% (CI 95% 2.53-2.88) to 3.39% (CI 95% 3.11-3.66). Due to population growth, absolute numbers with past 30-day cannabis use are estimated to increase from 202,784 (CI 95% 189,534-216,035) to 314,302 (CI 95% 288,504-340,100). Among those aged under 30 years no substantial change in lifetime and 30-days prevalence of cannabis use is projected. Larger changes are estimated to occur in the age group 30+. The mean age of past 30-day cannabis users would increase for men with Swiss nationality from 30.3 to 38.7 years.

Discussion: Population-based survey data and demographic projections can be used to develop baseline scenarios of future cannabis use. Assuming no changes in cannabis legislation, growing absolute numbers of users will likely increase treatment demand. Cannabis use is estimated to increase among the group aged >30 years, which is currently underrepresented in clinical treatment and research. Our findings highlight the need for prospective baseline scenarios to evaluate the impact of legislative changes on cannabis use. Moreover, in Switzerland effective prevention and treatment interventions for cannabis use disorders are required even if cannabis legislation remains unchanged.

Keywords: THC; Marijuana; Substance use; Demography; Drug policy; Prevalence

Introduction

Alternative cannabis regulation models are discussed or have been introduced in different countries and jurisdiction systems (Cerdá & Kilmer, 2017; Hall & Lynskey, 2016; Havemann-Reinecke et al., 2017). These regulations affect medical or recreational cannabis use, or both. However, critics of such approaches anticipate an increase of cannabis use and associated disorders (Budney & Borodovsky, 2017; Hall & Lynskey, 2016). Scientists and stakeholders have therefore called for the systematic collection of data to investigate the effects of changes in cannabis regulation on a population level (Kilmer & Pacula, 2017).

Evaluation of the effects of policy changes will need to consider population-based data, which account for developments of substance use as well as demographic changes, such as age distribution or migration. Demographic developments have already been projected for several decades into the future in statistical scenarios (Kohli, Bläuer, Perrenoud, & Babel, 2015). For example, the Swiss reference scenario predicts that in Switzerland the number of Swiss inhabitants will increase by about 14% between 2015 and 2045, whereas the Non-Swiss population will rise by about 57%. These scenarios of demographic developments need to be integrated in new models about predictions of future substance use. Such models would forecast prevalence of cannabis use across different age groups considering current and past developments. They would need to consider demographic scenarios, age-of-onset of cannabis use, lifetime morbid risk - i.e. the proportion of people that will eventually use cannabis at one point in their life -, as well as the likelihood of regularly using cannabis once it has been used for the first time. These models can serve as “baseline scenarios” to evaluate the effects of changes in cannabis legislation.

Here we aimed to estimate the current and future prevalence of cannabis use in Switzerland under the present legislation accounting for demographic development from 2015 to 2045.

Methods

We use data on cannabis use and other variables (age, gender, nationality) of the Continuous Rolling Survey of Addictive Behaviours and Related Risks (CoRolAR) mandated by the Swiss Office of Public Health from 2011-2015. This annual survey was conducted in four waves of equal size every three months. It used two sampling frames with randomly chosen persons reached via household phones and mobile phone numbers (random digit dialling) The survey comprised anonymous telephone interviews of about 11000 Swiss inhabitants 15 years and older. Adolescents and young adults are deliberately overrepresented and results weighted. Participation is voluntary. The response rate was 48% and the sample was considered representative for Switzerland. Further details about the survey and its methodology have been published elsewhere (Gmel, Kuendig, Notari, & Gmel, 2016).

All data from 56222 participants of the CoRoIAR 2011-2015 were included. In the pooled CoRoIAR surveys 2011-2015 the weighted data of 22 896 Swiss men, 24 609 Swiss women, 4 649 Non-Swiss men, and 4 067 Non-Swiss women were available. Age (in 1-year categories) varied between 15 and 98 years; mean age for Swiss women (44.8 years, SD 21.5) was higher than for Swiss men (42.4 Years, SD 21.5), Non-Swiss men (40.0 years, SD 18.2), and Non-Swiss women (40.1, SD 17.7).

A parametric model of age of onset of cannabis use (log-logistic distribution) and lifetime morbid risk for cannabis use in different birth cohorts (using logistic functions), and a 30-day persistency model (i.e. the prevalence by age group of past 30 days cannabis use among lifetime users, accounting for higher persistency for those who had an early age of onset) were developed using the pooled CoRoIAR surveys 2011-2015. We then constructed models of lifetime and 30-days prevalence until 2045 across gender, nationality (Swiss and Non-Swiss) and age groups. The demographic reference scenario "A-00-2015" 2015-2045 published by the Swiss Federal Statistical Office (Kohli et al., 2015) served to account for demographic trends by using population estimates for sex, nationality between 2015-2045 in 1-year steps . This method allows to control for birth cohort effects as well as the higher risk of persisting cannabis use with lower age of onset. We used PROC NLMIXED in SAS 9.4. Details of the statistical procedures are available in the supplementary material.

Results

The observed lifetime prevalence of cannabis use differed substantially by gender, nationality and year of birth (Figure 1). For all groups born 1995 and onwards a median age of first use of about 17 years was estimated (Swiss men 16.9 years (CI 95% 16.7-17.0); Swiss women 17.0 years (CI 95% 16.9-17.1); Non-Swiss men 17.3 years (CI 95% 17.1-17.5); Non-Swiss women 17.5 years (CI 95% 17.2-17.7)).

-figure 1 about here-

The lifetime morbid risk of cannabis use could be modeled with two increases, where those born in 1951 and in 1975, respectively, acted as midpoints (supplementary Figure 1). The maximum level of the first increase was estimated at 35.7% (CI 95% 32.6-38.8) for Swiss men and also for Non-Swiss men, 25.5% (CI 95% 23.0-28.0) for Swiss women and 20.4% (CI 95% 16.6-24.1) for Non-Swiss women. The maximum level of the second increase was strongest for Swiss men (31.8%, CI 95% 28.1-35.4), somewhat less pronounced for Swiss women (26.7%, CI 95% 23.5-29.9) but clearly lower in Non-Swiss men (11.4%, CI 95% 5.7-17.0) and Non-Swiss women (9.6%, CI 95% 2.9-16.3). Thus, the model predicts that the lifetime morbid risk of cannabis use will increase for future birth cohorts up to 67.5% (CI 95% 65.2-69.7) in Swiss men, 52.2% (CI 95% 49.9-54.5) in Swiss women, 47.0% (CI 95% 42.4-51.7) in Non-Swiss men and 30.0% (CI 95% 25.6-34.4) in Non-Swiss women.

Our model showed a gender-specific decrease with age in the 30-day persistency: 48.0% at 15 years, 12.9% at 30 years, 7.7% at 45 years for men; 39.6% at 15 years, 5.0% at 30 years, 2.1% at 45 years for women (Figure 2).

-figure 2 about here-

Lifetime prevalence of cannabis use in Switzerland in the whole population was forecasted to increase from 28.3% (CI 95% 27.8-28.8) in 2015 to 42.0% (CI 95% 41.0-43.0) in 2045, i.e. by a factor 1.48 (Figure 3, left). This increase is even stronger looking at the estimated absolute number of persons who have used cannabis during their lifetime at least once (factor=1.83; from 2,125,020 (CI 95% 2,087,093-2,162,948) in 2015 to 3,899,185 (CI 95% 3,805,471-3,992,899) in 2045).

-figure 3 about here-

However, 30-days prevalence for the whole population will increase only slightly (from 2.70% (CI 95% 2.53-2.88) in 2015, to 3.39% (CI 95% 3.11-3.66) in 2045), i.e. a factor of 1.25. Notably, due to population growth during that time span, the estimated number of people who used cannabis during the last 30 days will increase from 202,784 (CI 95% 189,534-216,035) in 2015 to 314,302 (CI 95% 288,504-340,100) in 2045, corresponding to a factor of 1.55 (Figure 3, right).

Swiss men are the only group, in which the forecasted proportion of the 30-days prevalence is clearly higher in 2045 (5.88%, CI95% 5.32-6.43) than in 2015 (4.38%, CI 95% 4.04-4.71). In contrast to this, in all four groups the absolute numbers of the forecasted 30-day prevalence will increase similarly, although the increase between 2015-2035 is more pronounced in women than in men (see supplementary Figure S2).

Moreover, the mean age in the group with past 30-days cannabis use will increase by 8.4 years for Swiss men (30.3 years (SD 12.2) in 2015; 38.7 years (SD 17.9) in 2045) and by 6.9 years for Swiss women (26.8 years (SD 11.2) in 2015; 33.7 years (SD 17.4) in 2045), whereas for the Swiss population (10-100 years) an increase of only 4.0 years and 3.6 years, respectively, is predicted (supplementary Figures S3 and 4). Notably, as the predicted demographic changes in the Non-Swiss population will lead to a stronger increase of the mean age for Non-Swiss men (6.8 years) and Non-Swiss women (7.0 years), the ageing among the group of the Non-Swiss past 30-days cannabis users will be similar (Non-Swiss men 32.9 years (SD 10.9) in 2015 and 40.8 years (SD 16.2) in 2045; Non-Swiss women (29.1 years (SD 10.3) in 2015; 35.3 years (SD 15.9) in 2045) (supplementary Figure S3).

-figure 4 about here-

The graphs in Figure 4 indicate lifetime (upper row) and 30-day prevalence (lower row) by group and age for 2015, 2030, and 2045. Overall, among the population up to 30 years of age there is no substantial change forecasted with respect to the absolute number and the proportion of lifetime and 30-days prevalence of cannabis use. The larger changes are predicted to occur in the group of persons above 30 years.

Discussion

Based on annual population survey data from 2011-2015, and assuming no further prevention measures or legislation changes with an effect on cannabis prevalence, almost half of the Swiss population will have at least some experience with cannabis use in 2045 compared to roughly a third in 2015. This sizable increase is predicted to happen under the current legislation and despite the fact that cannabis is currently illegal in Switzerland and underlines the failure of the present policy to achieve a reduction of use in the population. Other countries such as the US and New Zealand have already had a lifetime prevalence of comparable size since the early 2000s (Degenhardt et al., 2008). The increasing proportion of people with cannabis experience is likely due to several effects. The availability of cannabis has increased in the 1970s and stayed on a high level since (Johnston et al., 2018). Cannabis use is typically initiated in adolescence at age 16-22 and only very rarely after age 29 (Chen & Kandel, 1995; Degenhardt et al., 2008). Furthermore, there are cohort effects regarding attitudes and socialization that affect cannabis use. This is illustrated by the presented lifetime morbid risk model, which controls for age-of-onset and shows increasing cannabis use prevalence for the birth cohorts since 1930, plateauing around the cohort born in 2000. We identified two increasing phases with midpoint of those born in 1951 and those born in 1975. These increases differentially affected separate population groups, and men of Swiss nationality were the most affected group. Two out of three Swiss men born in 2000 or later will use cannabis at least once in their lifetime. This affects the future developments on the lifetime prevalence of cannabis use in the whole population as younger age cohorts confronted with high cannabis availability and with higher prevalence of lifetime cannabis use are aging, and the current older age cohorts with lower cannabis experience are diminishing.

Intuitively, one may expect that, corresponding to the growing lifetime prevalence, current cannabis use as measured by 30-day-prevalence would equally show a comparable increase. However, this is not the case. Projected 30-days prevalence of cannabis use only increases by a factor of 0.84 compared to lifetime prevalence in the presented model. This is mainly due to the fact that with increasing age, a person is less likely to continue using cannabis (Chen & Kandel, 1995). Still, the mean age of people with ongoing use in the past 30 days is projected to increase, illustrating that future cannabis use in Switzerland will nevertheless be more pervasive in higher age groups than it is now.

While the absolute number of adolescents and young adults using cannabis in the past 30 days is projected to change only marginally until 2045, the number of 30-day users aged 30 or above will increase substantially. This finding is relevant for future regulatory measures which will likely contain measures aimed at protecting adolescents from cannabis use, e.g. by introducing minimum legal ages for use similar to alcohol and tobacco. The effect of such measures would have to be evaluated against the comparatively small predicted change in this age group. At the same time, the increase in the age group above 30 may lead to an increase in treatment demand.

The major increases of cannabis use prevalence are projected to happen in the group aged above 30 years. Given longer duration of use and potential negative impact on role obligations such as in work or family, treatment demand by older individuals will likely grow and the treatment system may be confronted with a new patient group. The group of older cannabis users is currently still under-researched and rarely targeted by secondary prevention measures. It will be important to adapt existing treatment offers for younger patients to these patient groups. It is also unclear whether increasing cannabis use in elderly patients will be associated with currently unanticipated health consequences, be they harmful or beneficial. It will be important to monitor cannabis use and consequences in these population groups during this development.

Our model suggests a relevant increase of the number of people that have used cannabis in the past month by about 55% between 2015 and 2045. It is clear that having used cannabis in the last 30 days does not necessarily mean this use was in any way problematic. However, this increase may indeed lead to a growing treatment demand. In Switzerland and the European Union the proportion of substance use treatment seeking patients who received treatment for cannabis use has increased in the last decade, even in countries with decreasing prevalence such as Spain or the United Kingdom

(EMCDDA, 2017, 2018; Koordinationsgruppe Act-info, 2015). This development may reflect an increasing awareness of cannabis use disorders in these settings. There are also other factors that could potentially influence the proportion of cannabis use disorders and treatment demand, e.g. tetrahydrocannabinol (THC) concentration, or changing patterns of use. These were not considered in our model.

Baseline scenarios predicting future cannabis use have the advantage that, unlike retrospective models, they are independent of future trend changes or regulatory measures. The considerable increase of current cannabis users from about 200,000 in 2015 to 315,000 in 2045 is predicted to occur without changing cannabis legislation. Such a pronounced increase would likely not be explained retrospectively by trends already initiated in the past, but might be incorrectly attributed to social or political changes taking place during this period.

Our study has several limitations. The model only accounts for selected independent variables, which need to be gathered in population surveys. It does not account for other, unforeseen changes and developments that influence cannabis use and/or demographic developments, e.g. strong migration movements. Drug use is always influenced by time period and cohort effects. This is illustrated e.g. by the spiking incidence rate of opioid use in Switzerland in the 1980s and 1990s in Switzerland or currently in the United States (Martins et al., 2017; Nordt & Stohler, 2006). Such increases cannot be ruled out in the future, but cannabis use incidence and prevalence over the last 40 years suggest that cannabis use may be less prone to pronounced short-term changes and thus more suitable for long-term prospective modeling. In addition to policy changes in Switzerland itself, the major policy and market changes occurring both internationally (regulation of medical and recreational cannabis markets) and locally (for instance the Swiss cannabidiol market) will likely have an impact on cannabis use in Switzerland as well. Our model cannot account for that.

Our simple model does not include amount or frequency of cannabis use. From a public health perspective, in order to evaluate the effects of legislative changes, it would be desirable to assess whether there is an increase of non-problematic occasional users, or whether frequency and amount of cannabis use increase in certain smaller subgroups of the population. The latter would likely lead to more cannabis-associated problems and warrant targeted prevention addressing cannabis use in these vulnerable groups.

Conclusion

Population-based survey data and demographic scenarios can be used to develop models to forecast future development of cannabis use. These models may be useful as "baseline" scenarios to evaluate changes in cannabis use due to changes in cannabis regulation, to elucidate the need for specific preventive and therapeutic interventions given future demographic trends, and to evaluate the effect of specific targeted prevention measures. The presented model suggests a large increase of lifetime prevalence of cannabis use in the Swiss population until the year 2045 under the current legislation. The comparably lower increase of the proportion of current cannabis users nevertheless corresponds to a substantial increase in absolute numbers, which will likely result in an increase in treatment demand. Our findings highlight the need for the introduction and evaluation of effective prevention and treatment interventions for cannabis use disorders.

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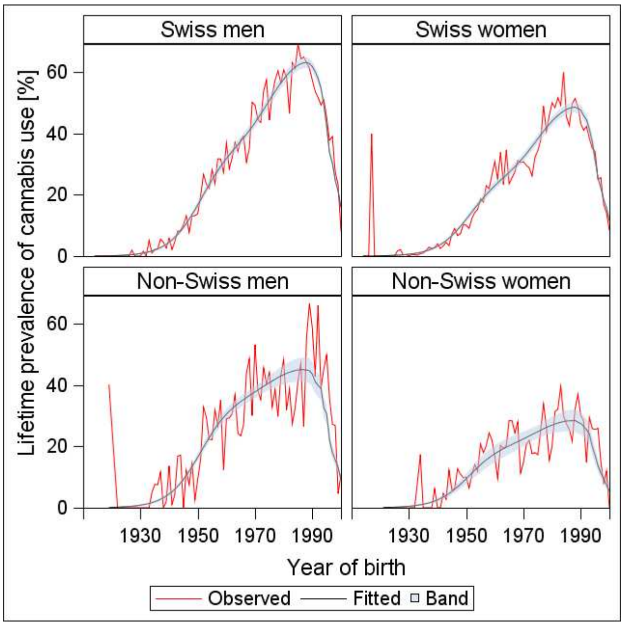

Figure 1: Observed and fitted lifetime prevalence of cannabis use in Switzerland by year of birth and group, CoRolAR 2011-2015.

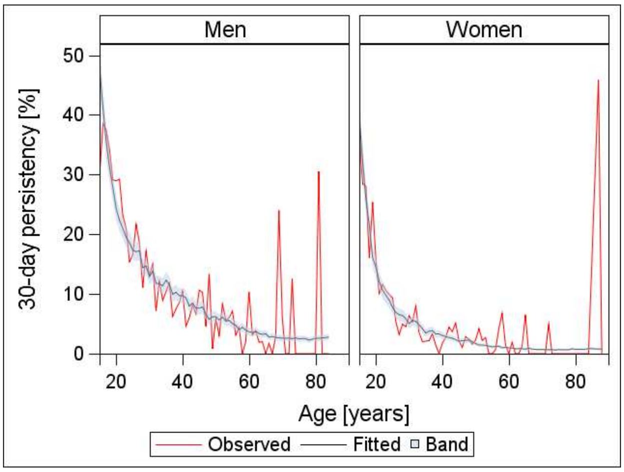

Figure 2: Observed and fitted 30-day persistency of cannabis use in Switzerland by age and gender (left: men; right: women), CoRoIAR 2011-2015.

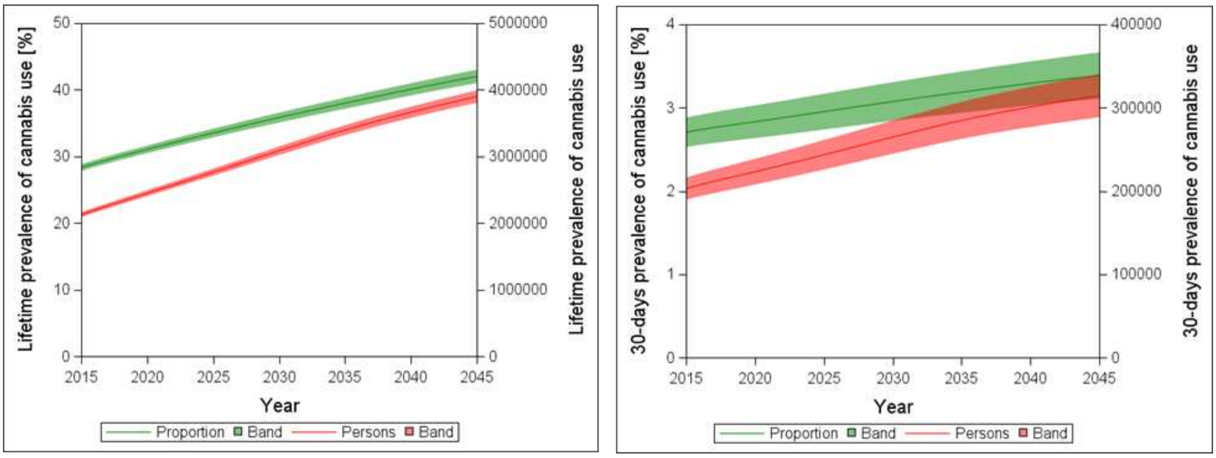

Figure 3: Forecasted lifetime prevalence (left) and 30-days prevalence (right) of cannabis use, Switzerland 2015-2045.

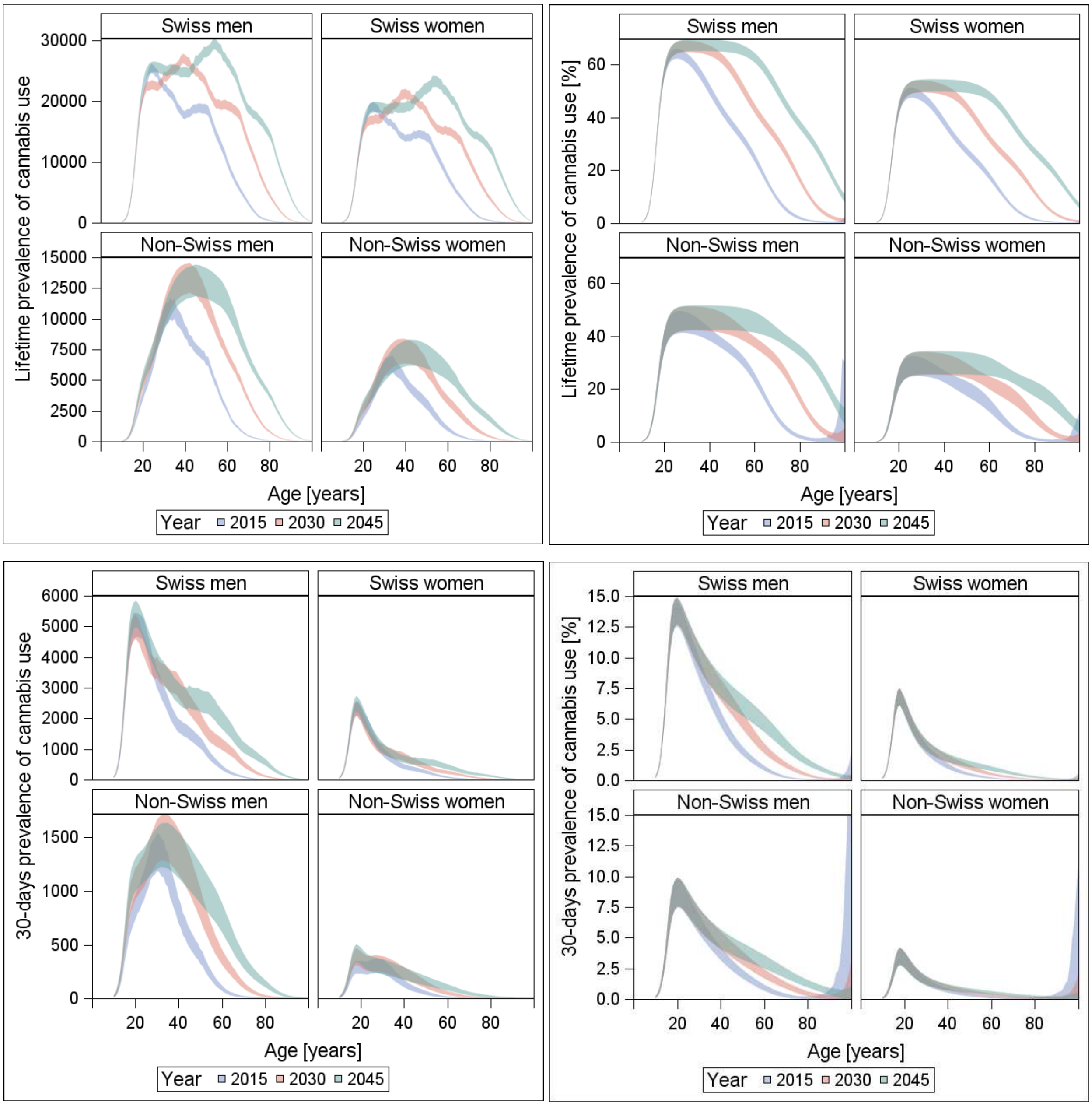

Figure 4: Forecasted number (left) and proportion (right) of lifetime prevalence (upper row) and 30-days prevalence (lower row) of cannabis use in Switzerland by group and age for 2015, 2030, and 2045.

Supplementary material

Statistical model specifications

Simple short time trends observed between 2011 and 2015 will not be appropriate to forecast prevalence of cannabis use between 2015 and 2045 as demographic developments over longer time periods affects birth cohorts differently and also will most often lead to a change in age distribution of a population. Moreover, young cannabis users in 2045 are not yet born and therefore some assumption of time trends must be applied.

In our model we assumed two different processes affecting lifetime experience of cannabis use. The first one is that not all persons start using cannabis at the same age. Hereby, we assume that such an age-of-onset distribution can be fitted by a parametric model. Usually, a Weibull distribution, a Gamma distribution, or a log-logistic distribution can be applied. The advantage of a parametric distribution is not only that it allows forecasting of age-of-onset distribution for past and future generations but also that it may help to correct biases of memory effects that are often connected with a preference for even numbers below twenty years and numbers above twenty years that are a multiplication of five.

When specifying a parametric survival model (e.g. PROC LIFEREG) it is necessary to identify observations that have not already experienced the event of interest (here the age of first use of cannabis); these cases are called (right) censored cases. For example, it is obvious that among a sample of 14 years old boys only some will have experience with cannabis, but others probably will try it during the following years. As survival analyses were initially developed for mortality studies it is assumed that each and every person will die in the long run, therefore, this assumption of total affection is accordingly programmed in PROC LIFEREG. This is a severe shortcoming as it is common knowledge that not all persons will ever try cannabis especially those born in the 40's or earlier. Example 64.5 in the SAS 9.4 documentation of PROC NLMIXED describes how to specify a parametric survival model. It is one of the key advantages of PROC NLMIXED that very different nonlinear mixed models can be specified which allows that the parametric survival model can be extended as follows. If assuming that a proportion D will ever experience the event of interest the following two lines of example 64.5 must be changed form:

```
G_t   = exp(-(alpha*minutes)**gamma);

g     = gamma*alpha*((alpha*minutes)**(gamma-1))*G_t;
```

to

```
G_t   = exp(-(alpha*minutes)**gamma)*D+(1-D);

g     = gamma*alpha*((alpha*minutes)**(gamma-1))* exp(-(alpha*minutes)**gamma)*D;
```

To state it simply, if 80 percent (D=.8) of the sample will ever experience the event of interest, the probability density distribution (g) and the cumulative probability distribution (G_t) must be weighted with D and the remaining proportion (1-D) is treated as permanently censored.

The proportion D need not be fixed to a stable value. Thus, one can formulate various functions for D, for example that it depends on year of birth. With the three following lines D we specified with two logistic functions where s1 and t1 signifies the maximum proportion of the increase, s2 and t2 the year of the midpoint of the increase and s3 and t3 the slope of the increase:

```
ss = exp((birth-s2)/s3);

 tt = exp((birth-t2)/t3);

 D = (s1*ss/(1+ss)+t1*tt/(1+tt));
```

To check if the model is correctly specified we compared the observed and the model fitted lifetime cannabis prevalence by year of birth and group in the pooled CoRoIAR surveys 2011-2015 (see Figure

1 in the main manuscript). As it can be seen in this figure the observed lifetime prevalence of cannabis use increases until the birth cohorts 1990 and declines because a substantial proportion of the younger generations had not reached their age of onset at the time of the CoRoIAR surveys.

For those born before 1995 we applied a linear ‘a1’ and a cubic ‘a2’ trend that fitted the higher age-of-onset by year of birth. For improving interpretation of estimates we had chosen to rescale the scale parameter ‘a0’ that it is identical with the median age-of-onset for those born in 1995. Therefore, we specified the rescaling term ‘a95’ as follows:

```
a95 = (a1*log(95)+a2*(log(95))**2);
```

The scale parameter ‘a’ of the log-logistic distribution depending on year of birth (‘birth’) was specified as follows:

```
a = exp(log(a0)+a1*log(min((birth-1900),95))+a2*(log(min((birth-1900),95)))**2-a95);
```

The estimated increase in median age-of-onset was rather small, for example for those born in 1980 it was 2.2% higher compared to those born in 1995, for those born in 1960 15.6% higher (meaning 19.5 years for Swiss men).

Inference based on a robust variance-covariance matrix of the model parameters via the EMPIRICAL option by declaring a random effect (‘normal(0,0)’) with survey participant as subject (see Vonesh E. Generalized Linear and Nonlinear Models for Correlated Data: Theory and Applications Using SAS. Cary: SAS Institute; 2012.).

The survey weight called ‘w3_weight_prop_new’ were applied in the replicate statement.

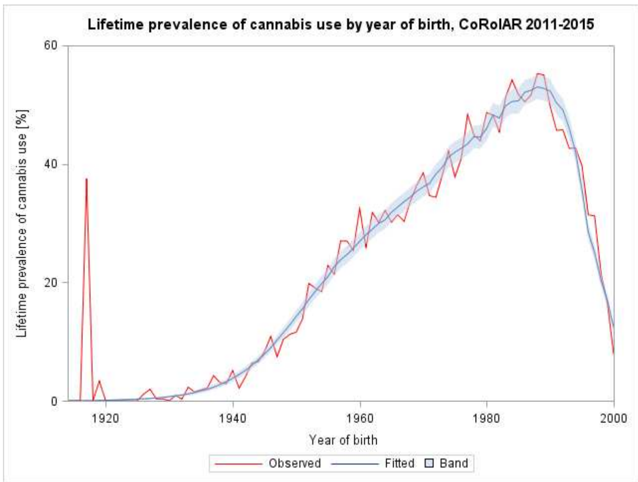

Figure S1: Lifetime prevalence of cannabis use by year of birth in Switzerland.

The model of 30-day-persistency showed a gender-specific decrease with age: e.g. for men: 48.0% (44.2-51.9) at 15 years, 12.9% (11.6-14.3) at 30 years, 7.7% (6.6-8.7) at 45 years; for women: 39.6% (36.1-43.1) at 15 years, 5.0% (4.2-5.9) at 30 years, 2.1% (1.7-2.5) at 45 years.

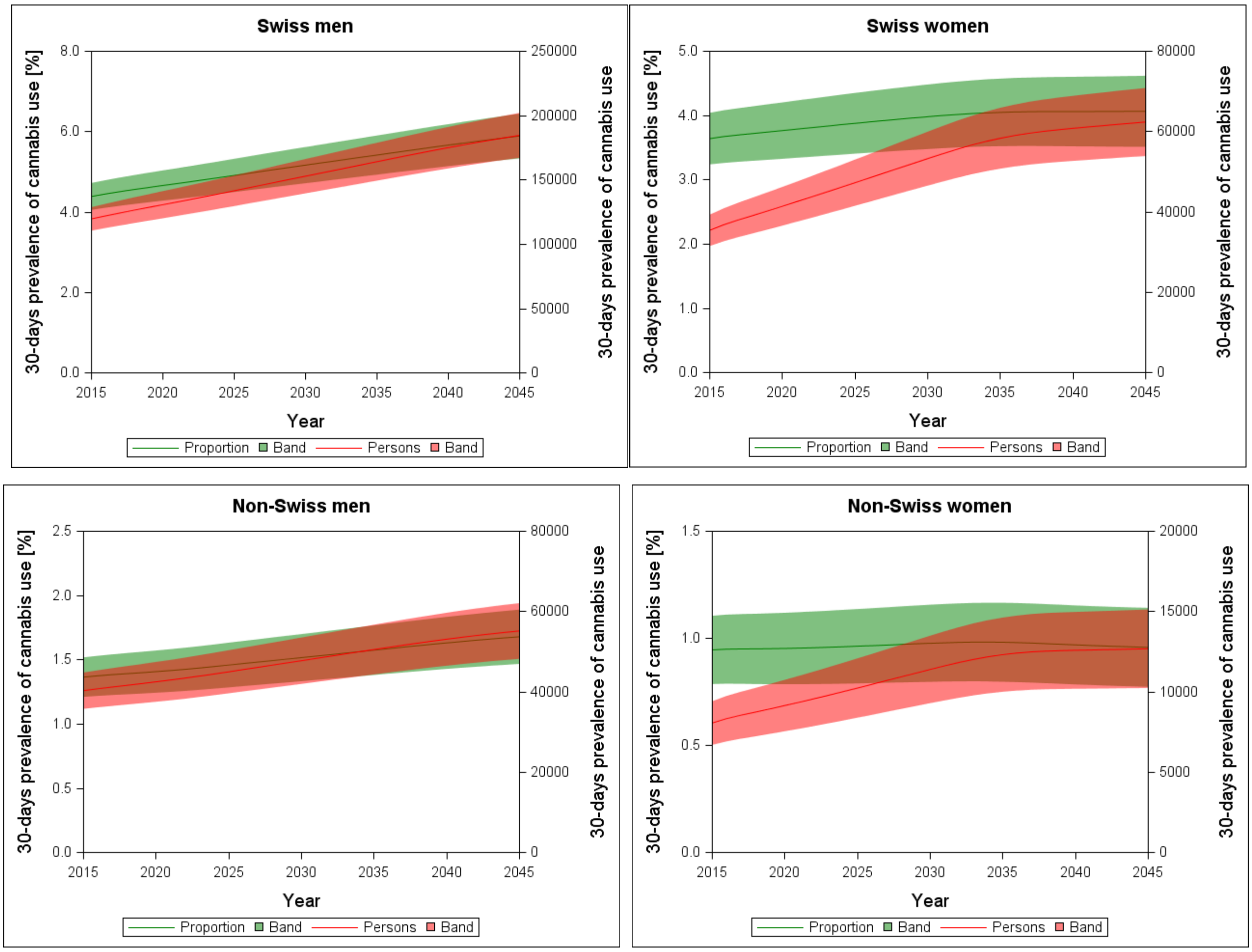

Figure S2: Forecasted 30-days prevalence of cannabis use by group, Switzerland 2015-2025.

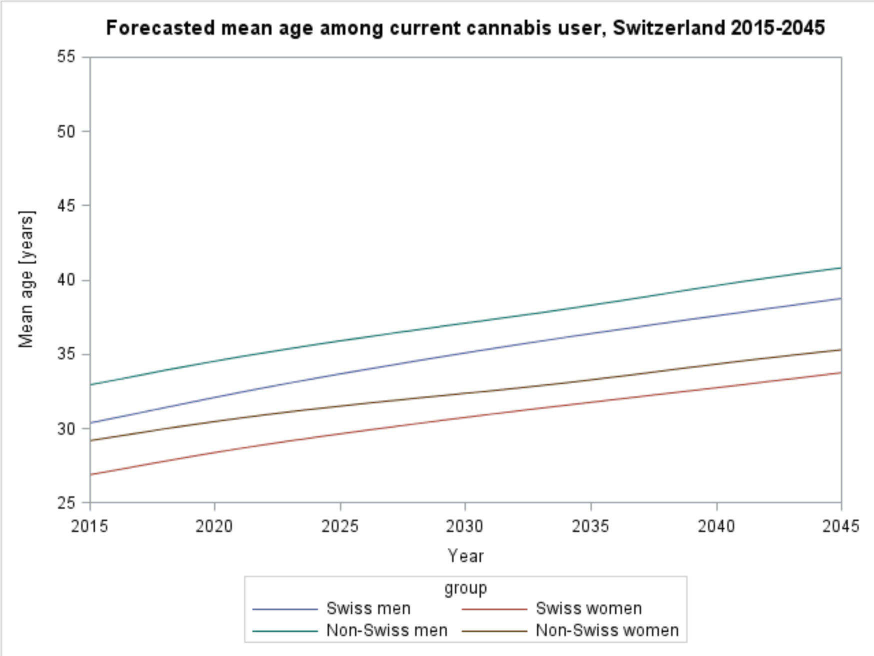

Figure S3: Mean age among current cannabis users in Switzerland 2015-2045.

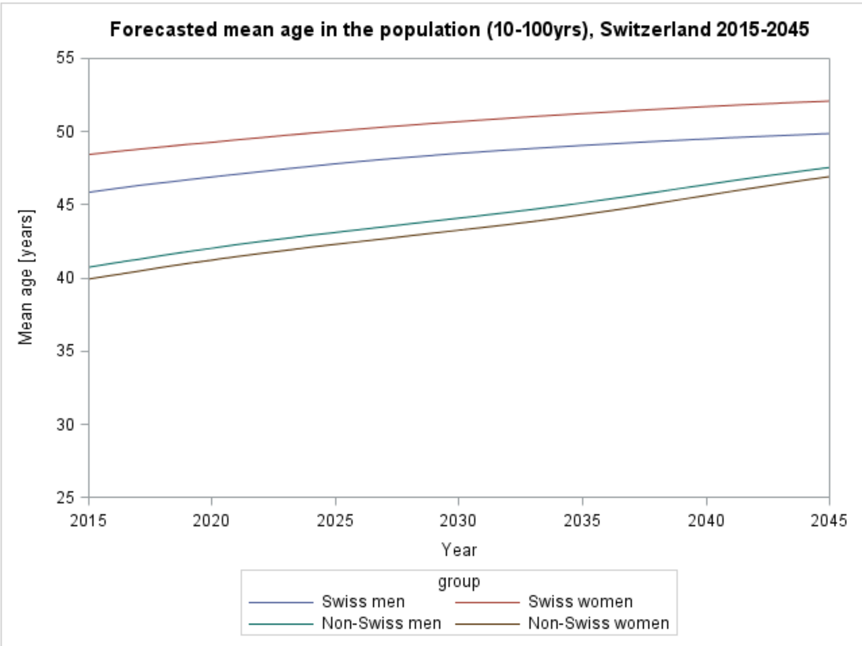

Figure S4: Mean age of the Swiss population 2015-2045.